

**Do Potted-Plants  
Improve  
the Indoor  
Environment?**

**Jason Brennan**

Thesis submitted to University of Technology, Sydney in fulfilment of the requirements for  
the degree of Master of Science in the Faculty of Science.

**2011**

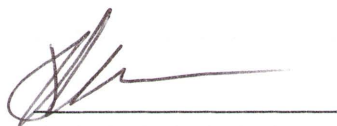
## Certificate of Authorship/Originality

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

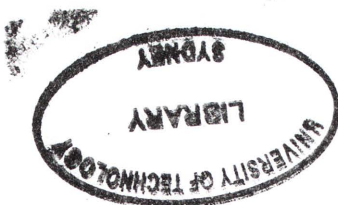
I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of Candidate

Date



28/07/11



## Acknowledgements

I would like to recognise Horticulture Australia Ltd (Commonwealth Horticultural R&D granting body), and the National Indoor Plants Association (NIPA) for their part in this project, for their funding and access to plant materials to conduct the experiments. NIPA is an industry peak body, promoting the use and appreciation of interior plants, including supporting research such as this project into potential benefits to health and wellbeing of indoor plant use.

A big thank you to all of the technical officers at UTS who make life so much easier in finding where things are, and how I can get my hands on it!

To my friends and family, for their patience and their support, especially to Mum for all the little (and sometimes big) things she does for me – I wouldn't have finished this without their understanding.

My Dad, who gave me the tools and knowledge to succeed in this and life in general. I wish I knew then what I know now. Your wisdom and skills are sorely missed.

To all of my research supervisors, past and present, Drs Alex Pulkownik, Andrea Leigh and Lisa Sedger, I greatly appreciate your interest and assistance; your backing meant I didn't miss out on this opportunity.

B2, you are a constant headache and delight at the same time. Thank you for pushing me over... the finish line.

Dr Fraser Torpy - you helped me with too many of my academic and personal issues the last couple of years. I really appreciate everything you have done for me. Thank you for always having *faith* in me.

Last but not least, Prof. Margaret Burchett, Meg. I am constantly in awe of the passion and drive that you have, especially faced with some of my more naïve questions or statements. I don't quite know how to express my gratitude to you for everything you have done (from editing to words of encouragement, and sometimes abuse!), except to say thank you very much!

Table of Contents

Certificate of Authorship/Originality ..... i

Acknowledgements ..... ii

List of figures .....viii

List of tables..... ix

List of abbreviations..... x

Abstract ..... xi

CHAPTER 1 Introduction..... 1

    1.1 Development of uses of indoor plants ..... 1

        1.1.1 Aims and context ..... 1

        1.1.2 History of uses of ornamental plants ..... 1

        1.1.3 Current uses of indoor plants..... 3

    1.2 Indoor environmental quality ..... 4

        1.2.1 Health concerns of indoor air quality ..... 4

        1.2.2 Indoor plants improve IAQ..... 6

        1.2.3 Other indoor plant benefits ..... 7

    1.3 Research objectives ..... 8

CHAPTER 2 Office study ..... 10

    2.1 Introduction..... 10

        2.1.1 Background and aims..... 10

2.1.2	Previous UTS studies.....	12
2.2	Materials and methods.....	15
2.2.1	Buildings .....	15
2.2.2	Experimental treatments.....	15
2.2.3	Equipment and procedures.....	17
2.2.4	Statistical analysis.....	18
2.3	Results.....	19
2.3.1	Temperature and humidity .....	19
2.3.2	TVOC and CO <sub>2</sub> levels .....	19
2.4	Discussion.....	22
2.4.1	Conditions of temperature and humidity.....	22
2.4.2	VOC reduction .....	22
2.4.3	CO <sub>2</sub> reduction .....	23
2.4.4	Significance of findings .....	24
CHAPTER 3 Laboratory studies – VOC removal.....		27
3.1	Introduction.....	27
3.1.1	Health effects of air-borne VOCs.....	27
3.1.2	Potted-plants reduce indoor urban air pollution .....	30
3.1.3	Experimental aims .....	31
3.1.4	Previous UTS studies of indoor plant VOC removal .....	31

3.2	Materials and methods .....	34
3.2.1	Plant materials .....	34
3.2.2	Model VOC .....	34
3.2.3	Equipment .....	35
3.2.4	Procedure .....	37
3.3	Results .....	38
3.4	Discussion .....	42
CHAPTER 4 Laboratory studies – CO <sub>2</sub> removal .....		45
4.1	Introduction .....	45
4.1.1	Potential benefits of indoor plantings for CO <sub>2</sub> removal .....	45
4.1.2	Study aims and context .....	46
4.1.3	Photosynthetic requirements of indoor plants .....	47
4.1.4	Photosynthetic pathways and other variables .....	48
4.1.5	Experimental aims .....	49
4.2	Materials and methods .....	50
4.2.1	Plant materials .....	50
4.2.2	Materials and procedures .....	50
4.3	Results .....	52
4.3.1	Water content of potting-mixtures .....	52
4.3.2	Results from leaf-chamber testing .....	53



4.3.3	Results from whole-potted-plant chambers.....	56
4.4	Discussion.....	60
4.4.1	<i>Spathiphyllum</i> 'Petite' .....	60
4.4.2	<i>Zamioculcas zamiifolia</i> .....	61
4.5	Significance of findings .....	62
CHAPTER 5 Does the presence of potted-plants affect indoor mould spore loads? .....		66
5.1	Introduction.....	66
5.1.1	Background.....	66
5.1.2	Mould spores as potential health hazards.....	68
5.1.3	Indoor mould health hazards .....	70
5.2	Materials and methods .....	72
5.2.1	Field sampling.....	72
5.2.2	Instrumentation.....	72
5.2.3	Colony identification.....	73
5.2.4	Potting-mix sampling .....	74
5.3	Results.....	75
5.3.1	Air sampling.....	75
5.3.2	Potting-mix spore abundance and diversity .....	80
5.4	Discussion.....	84
5.4.1	Overview of mould spore exposure .....	84

5.4.2	Mould diversity indoors and outside.....	84
5.4.3	Indoor plants as possible source of pathogenic mould spores.....	85
5.5	Summary/significance.....	86
5.5.1	Future research .....	88
CHAPTER 6 General discussion .....		89
6.1	Office study findings .....	89
6.1.1	CO <sub>2</sub> levels.....	89
6.1.2	TVOC levels.....	91
6.2	Laboratory studies – VOC removal .....	91
6.3	Laboratory studies – CO <sub>2</sub> removal.....	92
6.4	Effects of potted-plants on indoor air mould spore loads.....	93
6.5	Significance of findings .....	94
6.6	Future research directions .....	96
Outputs from project .....		99
7.1	Publications .....	99
7.2	Presentations.....	99
References .....		100
Appendix .....		115



List of figures

Figure 2.1.....17

Figure 2.2.....20

Figure 2.3.....21

Figure 3.1.....36

Figure 3.2.....39

Figure 3.3.....40

Figure 3.4.....40

Figure 4.1.....54

Figure 4.2.....55

Figure 4.3.....57

Figure 4.4.....57

Figure 4.5.....59

Figure 4.6.....59

Figure 5.1.....78

Figure 5.2.....79

Figure 5.3.....82

Figure 5.4.....82

List of tables

Table 3.1.....41

Table 4.1.....53

Table 5.1.....77

Table 5.2.....80

Table 5.3.....83

## List of abbreviations

ABPA	Acute Bronchopulmonary Aspergillosis
ANCOVA	Analysis of Co-Variance
ANOSIM	Analysis of Similarity
ANOVA	Analysis of Variation
CAM	Crassulacean Acid metabolism
HVAC	Heating, Ventilation and Air Conditioning
IAQ	Indoor Air Quality
IEQ	Indoor Environmental Quality
LRC	Light Response Curve
PDA	Potato Dextrose Agar
RBC	Rose Bengal Chloramphenicol Agar
SBS	Sick Building Syndrome
SDX	Sabouraud Dextrose Agar
TVOC	Total Volatile Organic Compound
UAP	Urban Air Pollution
VOC	Volatile Organic Compound
WHO	World Health Organisation
± SE	Standard Error of the mean

## Abstract

With increasing prevalence of urban air pollution (UAP), associated problems are becoming of major international concern environmentally, economically and with respect to human health. About 50% of the world's population (including 80% of Australians) live in urban areas and spend approximately 90% of their life indoors, where indoor air quality (IAQ) is almost always more polluted than outdoors, even in urban centres with the high reliance on fossil fuels for transport and industry. An increasing proportion of urban dwellers work in sealed buildings, dependent for air supply and thermal comfort on heating, ventilating, and air conditioning (HVAC) systems. This project investigated the potential benefits for more sustainable cities, that could be achieved by using potted-plants as a supplement to HVAC systems, with the added benefits of decreasing the incidence of sick building syndrome (SBS), and of lowering the carbon footprint of a city.

The research considered three major aspects of IAQ. Indoor plants have been shown to be able to significantly reduce levels of CO<sub>2</sub> and volatile organic compounds (VOCs), two classes of contaminants almost always found in higher concentrations indoors than outside. However, they have also been named as a likely source of pathogenic mould spores, and this was also investigated. An office field study was conducted in which the effects were tested of four plant treatments using *Dracaena marginate* 'Janet Craig' and *Spathiphyllum wallisii* 'petite' (plus reference offices) on a range of IAQ parameters: CO<sub>2</sub>, VOCs, temperature, relative humidity; plus airborne mould spore abundance and diversity. Laboratory studies were also carried out, on the capabilities of plants to: reduce CO<sub>2</sub> at different light intensities and from two different light acclimation intensities; remove benzene (as model VOC) applied at various dosages; and contribute to air-borne mould spore concentrations and species diversity.

Through the laboratory test-chamber studies it was shown that the three species tested; *Aglaonema modestum*, *Chamaedorea elegans* and *Philodendron* 'Congo' had the ability to remove the 8-hour averaged exposure limit after an induction period. Also plants were readily capable of reducing chamber CO<sub>2</sub> by up to 90% within one hour, under favourable lighting intensities and after two light acclimation levels. The mould studies revealed that, compared with outdoor air, there were 8–15 times lower mould spore loads indoors, and there was little correlation between the mould genera found in potting mix soil with those found in office air. The results indicate that it is unlikely that potted-plants are significantly contributing to the levels of moulds found in the air in Sydney. The office study, in two relatively new buildings, demonstrated that, with modern HVAC systems, indoor plants had little to no impact on IAQ, with no significant differences between offices with plants and those without. This is at variance with a previous study from this laboratory using two buildings with much older HVAC systems, and one with no air conditioning. Thus it appears that modern HVACs can mask any benefits of plants on IAQ. This result opens up the possibility of reducing the energy load on the HVAC system by allowing plants to play a greater role in cleaning indoor air. The results obtained in this study are very promising for future indoor environmental management. The possibility of reducing urban air pollution by lowering energy requirements of city buildings is also encouraging and, in a time of

emission trading schemes and carbon taxes, nature’s ability to cost-effectively mitigate urban pollution is impressive, and its development is urgently needed.